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Bureau of Solid Waste Management

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16. Abstracts The New Orleans East Incinerator has a design capacity of 400 tons per day, or 200 tons per day for each of its two identical reciprocating grate furnaces. It was designed for solid waste with a 5,000 Btu per lb heat content. During the study period, February 10 to 14, 1969, the burning rate of the unit studies, furnace No. 2, was 237 tons per day, or 18.5 percent above the design capacity. The average particulate emission rate for furnace No. 2 during the study period was 1.35 gr per scf (standard cubic foot) of dry flue gas corrected to 12 percent CO2. The incinerator process water discharged into the canal near the plant was approximately the same quanity as the well water, the original source of the process water. The total ownership and operating costs for the calendar year 1968 were $442,156. This was the cost of incinerating an average of 160 tons per day, or $9.36 per ton. An industrial hygiene survey of the incinerator found that during the study period the dust concentration and noise levels were below maximum permissible levels and presented no health hazard. A bacteriological study of the incinerator provided a comparison of the organisms in the solid waste and the residue.

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A STUDY OF THE

NEW ORLEANS EAST INCINERATOR

A Division of Technical Operations
Open-File Report (TSR/01.38/9)

written by JEFFREY L. HAHN, Engineer

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Solid Waste Management
1970

BACKGROUND

Incineration is an important method of solid waste processing in the United States, and although over 300 incinerators are in operation, little information on the performance of these units is available. It is therefore not surprising that the effects of incineration on the environment are little understood and frequently ignored.

An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents.

The Bureau of Solid Waste Management, through the Division of Technical Operations, has initiated a program to characterize the performance of incinerators of different designs and configurations. The primary objectives of this program are to produce basic information that identifies the results of the incineration process and to develop reliable sampling methodology.

During the studies it is considered necessary to make a complete analysis of all features that affect the operation of the facility as well as those that influence its potential for environmental pollution. The operation of the facility is not altered in any way unless specific study objectives dictate a change. Therefore, no special

effort is made to operate the facility at its design capacity; rather, it is tested at its "operating" capacity.

Reports from each study in this program will be prepared primarily for use by the management of the facility. Each report will contain only the data obtained during one individual study. Data comparisons with other studies will not be made in individual study reports. Summaries and comparisons of the data from all studies will be reported annually.

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DESCRIPTION OF FACILITY

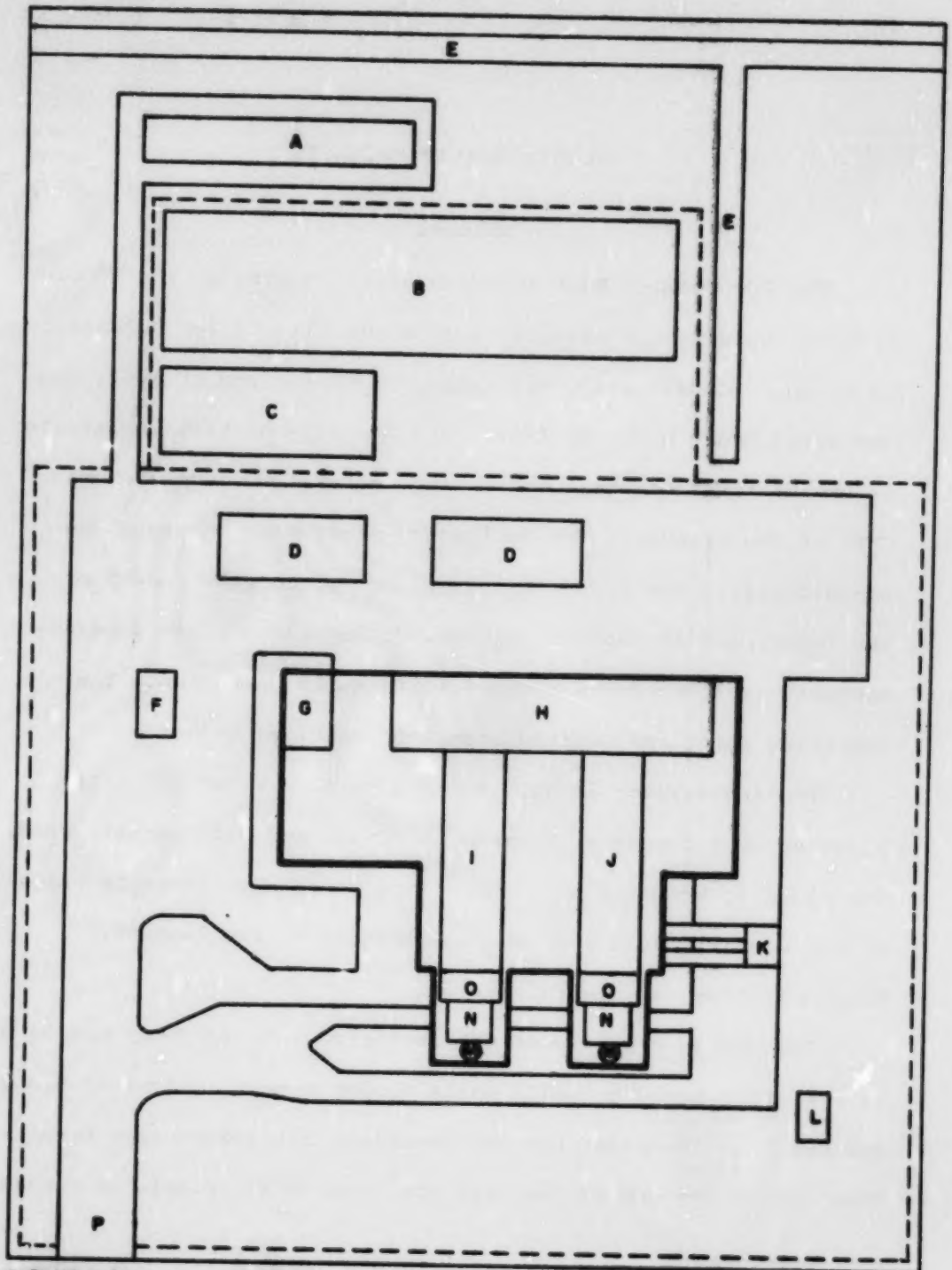
General

The New Orleans East Incinerator is located at 10,200 Old Gentilly Road in the eastern part of the City of New Orleans, Louisiana. Construction was completed at the end of 1967, and operation began early in 1968. The New Orleans East Incinerator is one of five incinerators serving the 625,000 people of the City of New Orleans. The incinerator operation is under the administrative control of Mr. F. E. Berry, Superintendent of the Department of Sanitation. Mr. J. Rogellio, plant superintendent, is directly in charge of its daily operation. The operating funds are derived from the municipal budget.

The incinerator is located in a rural part of the city bordered by a cemetery, a swamp, a canal, and Old Gentilly Road. The plant is bordered by a chain link fence with lockable gates on Old Gentilly Road and the road leading to the lagoons. Figure 1 shows the general layout.

The design capacity of the incinerator is 400 tons per 24 hr of operation based on solid waste having a heat content of 5,000 Btu per lb. The plant has two identical but independent furnaces. They are fed by one of two Shaw Box* over head travelling cranes

*Mention of specific products or equipment does not imply endorsement by the U.S. Public Health Service.



A. Residue fill
B. Settling lagoon
C. Sanitary lagoon
D. Truck garage
E. Canal
F. Scale
G. Office
H. Storage pit
I. Furnace # 1
J. Furnace # 2
K. Residue conveyor
L. Well
M. Stack
N. Multi-tube cyclone
O. Baffle wall and spray
P. Main entrance

Figure 1. General plant layout.

from a storage pit that can hold 1,750 cu yd of solid waste. The tipping area is open while the storage pit and the furnaces are enclosed in a concrete and brick building. Each furnace has its own stack and residue conveyor. The residue conveyors discharge into a central hopper for loading of the residue truck.

Furnaces

Each of the two identical furnaces (see Figure 2) was built by the Plibrico Company and is of the reciprocating grate type. Each furnace is lined with silicon carbide refractory brick, manufactured by the H. K. Porter Company, and has a total primary and secondary combustion chamber volume of 5,800 cu ft. The four Detroit reciprocating grate sections are 9 ft wide and are arranged in four descending steps. Each furnace has a total of 325 sq ft of exposed grate surface.

Combustion air is provided by separate underfire and overfire air fans. The underfire air fan is driven by a 20-hp motor and has a capacity of 20,000 cfm at 4½ in. water gauge pressure. The forced draft overfire air fan is driven by a 50-hp motor and has a capacity of 24,000 cfm at 10 in. water gauge pressure.

Air Pollution Control Equipment

After the gas stream leaves the secondary combustion chamber of the furnace, it passes under a vertical baffle wall equipped with a water spray. This water spray cools the gas stream before it enters the Multi-Tube cyclone dust collector. This cyclone is designed for a gas flow of 120,000 cfm at 600 F. A 150-hp induced

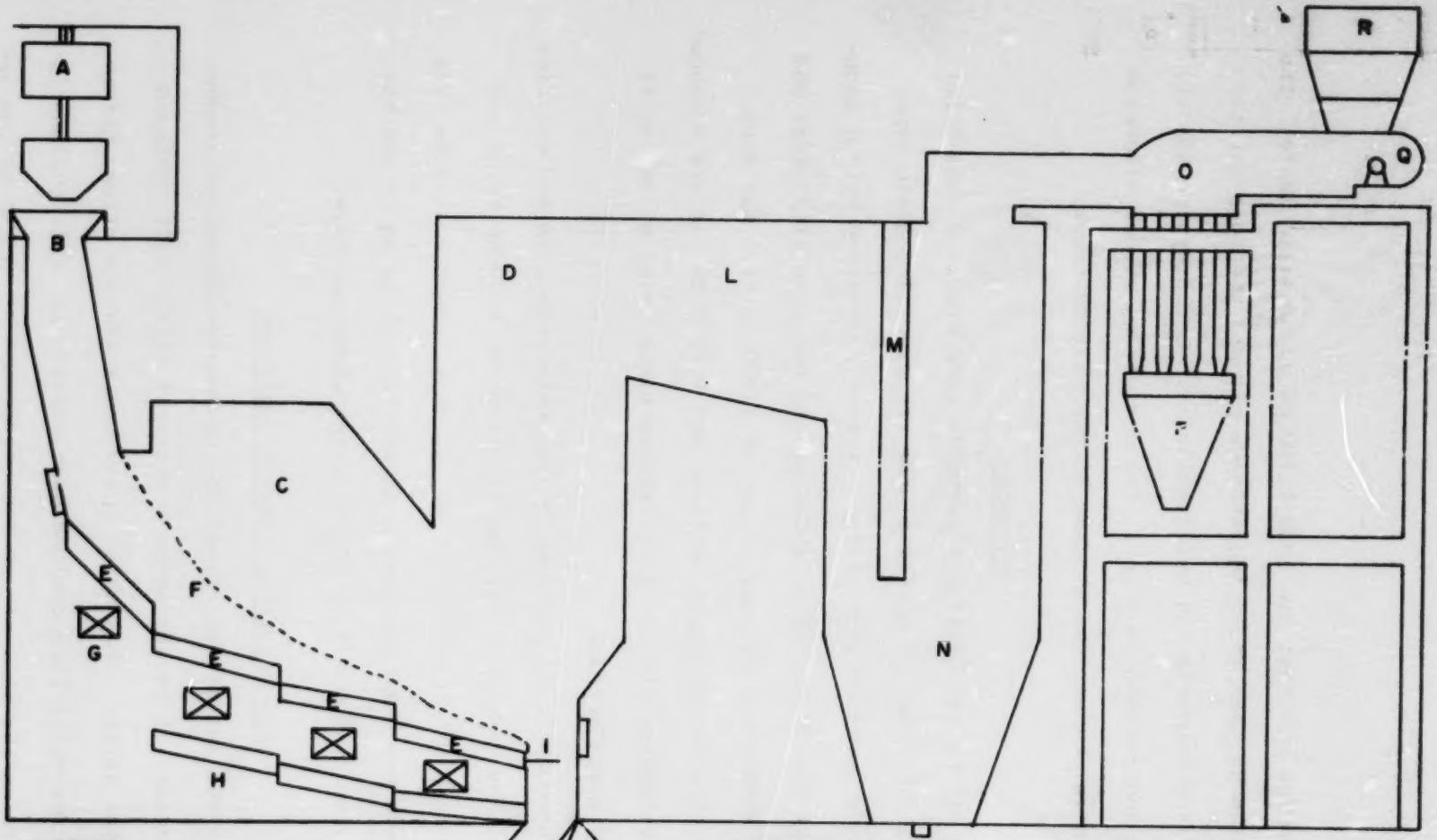


Figure 2. Incinerator cross section.

draft fan operates downstream from the cyclone to provide the draft. The gas stream finally exits from a 10-ft high stack approximately 72 ft above the ground (Figure 2).

Residue and Fly Ash Removal Systems

The residue from the furnace falls off the last section of the grates into either of two quench tanks. The quench tanks also serve as a collector for the spray water and the collected fly ash, which is flushed from the Multi-Tube cyclone hoppers into the quench tanks for removal with the residue. The combined residue and fly ash is removed from the quench tanks by conveyors into a common dumping hopper. When full, the hopper discharges the residue into a truck for disposal at a nearby landfill.

The process water is supplied by two wells, each equipped with a 500-gpm pump. The process waste water is discharged to a settling lagoon for treatment before it is finally discharged into a canal, while the plant sewage water is discharged to a sanitary lagoon for treatment.

Instrumentation

An upright Plibrico instrument panel is located in a room between the two furnaces on the furnace floor. This instrument panel contains continuous circular recorders and direct reading gauges for the primary combustion chamber and cyclone temperatures. An automatic bell

and light warning system is provided to alert the operating personnel of severe changes in temperature.

There are draft gauges located on the panel for the overfire air, underfire air, and the primary chamber, along with a manual underfire air and an automatic overfire air damper adjustment. Also, the panel contains a control for regulating spray water flow. Grate speeds are manually regulated by controls located on the side of each furnace.

Operation

The incinerator normally operates 24 hr a day from early Monday morning to late Saturday afternoon. Fire-up is started, with the use of natural gas, as soon as there is sufficient solid waste for normal operation on Monday morning, and furnace shut-down is completed on Saturday afternoon to allow for general maintenance.

All incoming solid waste is weighed, as well as the residue as it leaves the incinerator for landfilling. An average bucket load weight is determined several times a day by weighing three bucket loads dropped through a special chute into a truck. The number of buckets loaded into each furnace is noted on the circular temperature charts. At the end of each day, a record of the calculated weight of solid waste charged, along with the measured weight of incoming solid waste and removed residue, is compiled.

The work day is divided into four 6-hr shifts. There are five regular jobs: foreman, craneman, charger, ash truck driver, and

scaleman, along with general laborers. The foreman directs the operation making sure that the furnace and cyclone collector temperatures are in the correct ranges and the degree of burnout is sufficient. With the use of air dampers, variable grate speeds, and the spray water control, the problems of clinker formation, ash slag accumulation, and high Btu value incoming solid waste are dealt with as they occur during the normal operation.

METHODS AND PROCEDURE

Field Characterizations

Solid Waste

The weight of the incoming solid waste as charged to the furnace was determined by a unique method. From one to five times during the day, three bucket loads were dumped through a special chute into a truck and weighed and the average weight recorded. At the end of the day, these average bucket weights are averaged, and from this value, along with the number of buckets dumped during the entire day, the daily weight of solid waste burned is calculated.

To determine the physical composition of the solid waste, eight samples, weighing approximately 200 to 450 lb each, were taken to be sorted during the study period. Before separation, a density determination of the sample was made by filling a 24-gal container to the top without compaction, and determining the weight of the contents. The solid waste samples were hand separated into the following nine categories:

1. food waste
2. garden waste
3. paper products
4. plastics, rubber, leather
5. textiles
6. wood
7. metals
8. glass and ceramics
9. ash, dirt, rock, etc.

After separation, each of the nine categories was weighed. The total sample weight was then computed and the percentage by weight of

each category was determined. Using these percentages, four 10- to 15-lb samples were reconstructed by weight from the combustible categories (No. 1-6 above), placed in two plastic bags (knotted independently to prevent moisture loss), and placed in a 24-gal plastic container for transportation to the laboratory. The remaining noncombustible categories were discarded after being weighed. Also, one unseparated sample was returned to the laboratory for a check on the moisture analysis.

Residue

Four samples, weighing approximately 35 to 60 lb each, were taken from the conveyor of the furnace being tested during the study period. Before separation, a density determination of the sample was made by filling a 6-gal container to the top without compaction and determining the weight of the contents. Each residue sample was separated into the following four categories:

1. metals
2. glass, ceramics, rocks, bricks, etc.
3. unburned paper, organics, charcoal, etc.
4. fines (unidentifiable material passing through a ½-in. mesh screen)

After the larger pieces of each category were removed the remainder of the sample was sifted through a ½-in. mesh screen to remove the fines. The weight of each category was recorded and the unburned organics, (category No. 3), placed in a small plastic bag,

along with the fines (category No. 4), were placed in two independently knotted plastic bags and put in a 24-gal plastic container for transportation to the laboratory.

Fly Ash

Six samples, of approximately one liter, were taken from the Multi-Tube cyclone hopper over a three day period. The samples were put in a plastic Cubi-tainer and sealed for transportation to the laboratory. The density of the fly ash was determined in the laboratory.

Liquid

Composite samples (composed of two 500-ml grab samples) of liquid effluents were taken in the morning and afternoons of the days when stack testing was done. All samples were approximately one liter, and they were taken from the following four sources: spray water; fly ash flushing water; combined spray, fly ash flushing and quench water; and settling lagoon effluent. One liter grab samples were taken once a day from sanitary lagoon water and the well water. The samples were tested for pH and temperature in the field, and then they were sealed, labeled, and returned to the laboratory for determination of physical and chemical characteristics.

Instrumentation

During each stack test conducted in the study period, a record was kept of the temperatures, drafts, and grate control settings of

the No. 2 furnace. Also, measurements of the flame temperature were made with an optical pyrometer.

Stack

The effluent from the stack of the No. 2 furnace was sampled to determine the amount of particulate matter entrained and discharged with the stack gases. The procedure for the particulate sampling was based on that described in the "Specifications for Incinerator Testing at Federal Facilities."[1] An Orsat apparatus was used to determine the amount of carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) in the stack gases. A series of nine stack tests were performed during the study period.

The visible emissions were recorded during each stack test using the Ringelmann Scale for black smoke density and the Opacity Scale for white smoke density.

Industrial Hygiene

During the study period, a survey of the plant was performed by an industrial hygienist to identify those areas in the plant where workers were steadily employed and other areas of possible high exposure to environmental hazards. At these designated areas, tests were performed on noise level, dust, heat stress and effective heat and lighting.

Biological

Samples for microbiological analysis were collected from the following sources: solid waste, residue, quench water, well water, fly ash, and stack emissions.

These samples were returned to a near-by laboratory for the following analyses which began within hours of the time the samples were collected: total microbial count, heat resistant spores (aerobic and anaerobic), total coliforms, fecal coliforms, and Salmonellae.

Laboratory Procedures

Laboratory analyses of the incoming solid waste, furnace residue, and fly ash samples were conducted to determine moisture content, volatile and ash fractions, and the heat content values.

The combustible fractions of the incoming solid waste samples were processed through a hammermill which reduced the size of the material to about 1 in. maximum dimension. This ground product was spread on a plastic sheet and thoroughly mixed. The sample was then successively quartered and remixed, discarding alternate quarters. The process was repeated until a final sample of 3 to 5 lb was obtained.

The incinerator residue samples returned to the laboratory, consisting of the unburned organics and fines (everything but the metals; glass and ceramics; and ash, dirt, and rocks) were prepared

for analyses by mixing and quartering as above to reduce the sample size to 3 to 5 lb.

The fly ash samples did not require pretreatment, and the density was determined by weighing the uncompacted contents in a volumentric cylinder.

After grinding and/or sample size reduction, the solid waste, residue, and fly ash samples were analyzed according to the same procedure. Approximately 100-gm portions were dried at 70 C to constant weight for determination of moisture content. The entire dried samples were then cooled and ground in a Wiley mill to pass through a 2-mm mesh sieve. The volatile and ash determinations were performed on the dried samples according to the procedures outlined in Appendix A of Municipal Refuse Disposal.[2] The heat content of the dried solid samples was determined in a Parr Adiabatic calorimeter using the method described in "Operating the Adiabatic Calorimeter".[3] It should be noted that a combustion aid was necessary to determine the heat content of the residue.

All analyses of the liquid samples were performed according to methods published in Standard Methods for Examination of Water and Wastewater,[4] except for the phosphate analysis.[5]

The analysis of the stack effluent particulate samples was performed according to procedures described in "Specifications for Incinerator Testing at Federal Facilities".[1]

The analyses for the biological organisms were performed according to the procedures described in "Bacteriological Study of the New Orleans Incinerator".[6]

An ultimate analysis[7] for carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, and ash was performed, in triplicate, on one incoming solid waste sample and one residue sample.

RESULTS AND EVALUATION

Solid Waste Processed

From Monday, February 10 to Friday, February 14, 1969 the solid waste processed by the No. 2 furnace at the New Orleans East Incinerator was determined and the results are shown in Table I. The furnace was charged with an average of 250 bucket loads per day weighing an average of 1,903 lb per bucket. This loading of 237 tons per day is 18.5 percent above the 200 tons per day design capacity of the furnace. During this period, the average burning rate was 10.0 tons per hr.

Solid Waste Composition, Density and Heat Content

The average physical composition of the solid waste received at the incinerator during the study period is shown in Table II. A total of eight samples were sorted; the average sample weight was 300 lb. The composition by weight and percentage of each sample is shown in Table III.

The average density of the solid waste received was 230 lb per cu yd. The density of each of the samples is shown in Table IV, with the sample numbers corresponding to those above.

Four solid waste samples were returned to the laboratory for proximate analysis. The heat content, moisture content, and ash and volatile contents are shown in Table V (see Appendix I).

TABLE I

SOLID WASTE PROCESSED BY FURNACE NUMBER 2

Date	Input					Output			Operating time (hr)	Burning rate (tons/hr)
	No. of bucket loads	Average weight of bucket load (lb)	"As Received" weight (tons)	Moisture content (%)	Dry weight of solid waste (tons)	Wet weight of residue (tons)	Moisture content (%)	Dry weight of Residue (tons)		
Feb. 10	275	1,720	236	25.6(1)	176	78	12.2(1)	68	24	9.8
Feb. 11	247	1,942	240	27.2	175	80	12.2	70	24	10.0
Feb. 12	233	2,112	246	28.5	176	70	7.0(2)	65	24	10.2
Feb. 13	272	1,883	256	29.6	180	110	9.7	99	24	10.7
Feb. 14	223	1,860	207	29.6(3)	146	98	9.7(3)	88	22	9.4
Total	1,250	-	1,185	-	851	436	-	390	118	-
Average	250	1,903	237	28.1	170	87	10.2	78	23.6	10.0

(1) Moisture content from first sample taken on February 11

(2) Average moisture content for samples taken on February 12

(3) Moisture content from February 13

TABLE II

AVERAGE PHYSICAL COMPOSITION OF INCOMING SOLID WASTE

Category	Percent by Weight (as received)
Food waste	11.0
Garden waste	9.8
Paper products	44.9
Plastic, rubber, leather	3.5
Textiles	3.2
Wood	3.1
Metal	8.1
Glass, ceramics	9.5
Ash, rocks, dirt	6.9
Total	100.0
Combustibles	75.5
Noncombustibles	24.5

TABLE III

PHYSICAL CHARACTERISTICS OF INCOMING SOLID WASTE SAMPLES (AS RECEIVED)

Sample	(1) 2-11-69*		(2) 2-11-69		(3) 2-11-69*		(4) 2-12-69		(5) 2-12-69*		(6) 2-12-69		(7) 2-12-69		(8) 2-13-69*	
Component	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)	Weight (lb)	(%)
Food waste	54.75	12.6	31.50	11.4	52.80	16.9	16.50	7.8	14.75	7.3	16.00	5.9	34.00	9.6	55.00	16.4
Garden waste	47.25	10.9	45.80	16.5	12.40	3.9	19.00	9.0	20.00	9.8	26.00	9.5	50.50	14.2	14.75	4.4
Paper products	179.75	41.5	128.50	46.4	138.70	44.3	109.55	52.0	94.50	46.4	134.50	49.3	150.00	42.2	125.75	37.5
Plastic, rubber, leather	16.75	3.9	6.75	2.4	6.60	2.1	6.20	3.0	11.00	5.4	9.50	3.5	14.00	3.9	12.75	3.8
Textiles	25.00	5.8	4.75	1.7	11.20	3.6	8.25	3.9	7.75	3.8	7.50	2.7	7.25	2.0	8.00	2.4
Wood	11.00	2.5	0.50	0.2	7.25	2.3	5.10	2.4	14.75	7.3	5.00	1.8	2.25	0.6	25.00	7.4
Metal	38.75	8.9	19.55	7.0	30.00	9.6	15.00	7.1	14.75	7.3	21.50	7.9	29.50	8.3	28.20	8.4
Glass and ceramics	37.50	8.7	21.25	7.7	33.10	10.6	19.00	9.0	16.00	7.8	33.50	12.3	29.75	8.4	38.25	11.4
Ash, rocks and dirt	22.50	5.2	18.50	6.7	21.10	6.7	12.25	5.8	10.00	4.9	19.50	7.1	38.50	10.8	28.00	8.3
Totals	433.25	100.0	277.10	100.0	313.15	100.0	210.85	100.0	203.50	100.0	273.00	100.0	355.75	100.0	335.70	100.0
Percent combustibles	77.2		78.6		73.1		78.1		80.0		72.7		72.5		71.9	
Percent noncombustibles	22.8		21.4		26.9		21.9		20.0		27.3		27.5		28.1	

*Samples returned to the laboratory

TABLE IV

INCOMING SOLID WASTE DENSITY "AS RECEIVED"

Sample	1	2	3	4	5	6	7	8
Density (lb/cu yd)	-	211	278	-	157	294	197	216

TABLE V

TOTAL HEAT, MOISTURE, AND ASH AND VOLATILE CONTENTS (AS RECEIVED): INCOMING SOLID WASTE

Sample	Date	Heat content Btu/lb	% Ash	% Volatiles	% H_2O
1	2-11-69	4,332	29.9	44.5	25.6
3	2-11-69	3,620	32.6	38.5	28.9
5	2-12-69	4,223	24.7	46.8	28.5
8	2-13-69	3,311	34.3	36.1	29.6
Average		3,872	30.4	41.4	28.2

Residue and Fly Ash Composition, Density and Heat Content

The average composition of the residue leaving the incinerator during the study period is shown in Table VI. A total of four samples were sorted; the average sample weight was 44.5 lb. The composition by weight and percentage of each sample is shown in Table VII.

The average density of the residue leaving was 1,600 lb per cu yd. The density of each of the four samples is shown in Table VIII.

Four samples were returned to the laboratory for proximate analysis. The results of these analyses of the organics and fines components give ash and volatiles, moisture content, and heat content available. These values are shown in Table IX; in this case, the heat content is reported on a dry basis, (see Appendix I).

Six samples of fly ash were returned to the laboratory for analysis of heat content available and ash and volatile contents. These values are shown in Table X; in this case, the heat content is reported on a dry basis (see Appendix I).

The average density of the fly ash was 1,140 lb per cu yd. The densities of the six samples are shown in Table XI.

TABLE VI

AVERAGE PHYSICAL COMPOSITION OF RESIDUE

Category	Percent by Weight (as sampled)
Metal	20.0
Glass, ceramics	26.3
Fines	52.6
Unburned combustibles	1.1
Total	100.0

TABLE VII

PHYSICAL COMPOSITION OF RESIDUE SAMPLES
(as sampled)

Sample	(1) 2-11-69		(2) 2-12-69		(3) 2-12-69		(4) 2-13-69	
Component	Weight (lb)	%	Weight (lb)	%	Weight (lb)	%	Weight (lb)	%
Metal	9.60	21.2	6.75	19.0	8.20	21.2	10.75	18.5
Glass, ceramics	9.50	20.9	10.25	28.8	11.85	30.6	14.50	25.0
Fines	26.00	57.3	18.10	50.8	18.60	47.9	31.50	54.3
Unburned combustibles	0.25	0.6	0.50	1.4	0.10	0.3	1.25	2.2
Total	45.35	100.0	35.60	100.0	38.75	100.0	58.00	100.0

TABLE VIII

RESIDUE DENSITY
(as sampled)

Sample	1	2	3	4
Density (lb/cu yd)	1,577	1,415	1,334	2,068

TABLE IX

TOTAL HEAT AND ASH AND VOLATILE CONTENTS (DRY BASIS): RESIDUE

Sample	Date	Heat content Btu/lb	% Ash	% Volatiles	% H_2O
1	2-11-69	103	99.09	0.91	12.2
2	2-12-69	57	99.67	0.33	7.9
3	2-12-69	51	99.65	0.35	6.1
4	2-13-69	64	99.34	0.66	9.7
Average		71	99.44	0.56	9.0

TABLE X

TOTAL HEAT AND ASH AND VOLATILE CONTENTS
(DRY BASIS): FLY ASH

Sample	Date	Heat Content Btu/lb	Volatiles %	Ash %
1	2-11-69	565	5.6	94.4
2	2-11-69	455	4.0	96.0
3	2-12-69	600	2.5	97.5
4	2-12-69	420	3.6	96.4
5	2-12-69	275	6.0	94.0
6	2-13-69	335	3.2	96.8
Average		442	4.2	95.8

TABLE XI

FLY ASH DENSITY
(as sampled)

Sample	1	2	3	4	5	6
Density (lb/cu yd)	934	1,153	907	1,328	1,320	1,193

Ultimate Analyses

The results of the ultimate analysis on the portions of the incoming solid waste and residue samples returned to the laboratory are shown in Table XII. The samples were analyzed for the percent by weight of carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, and ash, and they are shown adjusted to the total sample basis.

TABLE XII

ULTIMATE ANALYSIS: INCOMING SOLID WASTE AND RESIDUE

Sample	Incoming solid waste				Residue			
Component	8a (%)	8b (%)	8c (%)	Avg. (%)	4a (%)	4b (%)	4c (%)	Avg. (%)
Moisture	29.70	29.70	29.70	29.70	8.32	8.32	8.32	8.32
Ash	31.64	31.32	31.56	31.50	90.61	90.58	90.61	90.59
Carbon	19.03	19.22	19.11	19.12	0.07	0.06	0.07	0.07
Hydrogen	0.93	1.08	1.04	1.02	0.01	0.01	0.01	0.01
Oxygen	18.18	18.11	18.04	18.11	0.82	0.85	0.82	0.83
Sulfur	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
Chlorine	0.22	0.22	0.22	0.22	0.06	0.05	0.05	0.06
Nitrogen	0.25	0.30	0.28	0.28	0.05	0.07	0.06	0.06
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Solid Waste Reduction

The previous sections contain the data necessary to calculate four determinants of the efficiency of the No. 2 furnace at the New Orleans East Incinerator. The first determinant is the overall weight reduction efficiency of the furnace on a dry basis. For the test period, the overall weight reduction efficiency was approximately 53 percent (see Appendix II).

The next determinant is the overall volume reduction efficiency of the furnace on a wet basis. For the test period, the overall volume reduction efficiency was approximately 94 percent (see Appendix II).

The next determinant is the volatile weight reduction efficiency of the furnace on a dry basis. For the test period, the volatile weight reduction efficiency approached 100 percent (see Appendix II).

The last determinant is the available heat released by the furnace. For the test period, the available heat released was approximately 99 percent (see Appendix II).

Particulate Emissions

During the study period, a total of nine stack tests were conducted. The results of these tests are shown in Table XIII. The particulate emissions are expressed in two manners: weight emissions and average visible emissions. The complete visible emission readings for each stack test are presented in Appendix III.

TABLE XIII

STACK TEST RESULTS OF FURNACE NUMBER 2

Date	Test number	Time of day	Percent CO_2 in stack gases	Feed rate tons/hr	Particulate emissions					
					Weight emissions				Visible emissions*	
					Gr/scf at 12% CO_2	Lb/hr	Lb/ton solid waste	Lb/1,000 lb of dry flue gas at 50% excess air	Ringelmann number	Opacity (%)
Feb. 11	1	10:56 -12:40	3.46	10.6	2.09	330	31.2	4.42	1.50-2.25	50-60
Feb. 11	2	2:20 - 3:10	3.72	11.6	1.92	306	26.4	3.95	0.75-2.00	-
Feb. 11	3	4:07 - 4:44	3.21	12.1	1.36	186	15.3	2.77	1.50-2.00	-
Feb. 12	4	9:10 - 9:46	2.62	6.8	1.75	191	28.2	3.52	1.00-1.50	10-50
Feb. 12	5	10:46 -11:22	2.72	7.9	0.84	101	12.9	1.63	1.00-1.50	10-40
Feb. 12	6	1:13 - 1:49	3.15	8.2	1.07	148	18.0	2.10	0.75-1.25	-
Feb. 12	7	2:41 - 3:25	3.37	7.4	1.09	173	23.4	2.16	0.75-1.75	-
Feb. 13	8	9:22 -10:17	3.32	10.6	1.22	177	16.8	2.58	-	40-60
Feb. 13	9	11:18 -11:54	3.47	10.4	0.78	122	11.8	1.49	-	15-60
Average			3.23	9.5	1.35	193	20.4	2.74	0.75-2.25	10-60

*Range of observations

Liquid Effluent

The results of the laboratory analysis on the liquid sources sampled are shown in Table XIV. A well on the incinerator grounds supplies the spray, quench, and fly ash water. The spray water, used for cooling the flue gas, and the fly ash water, used to sluice the fly ash from the Multi-Tube cyclones' hopper, are combined with the quench water in the quench tank. The combined spray, fly ash, and quench water is pumped to the settling lagoon, and after settling, the water is drained into a canal leading into the Mississippi River. City water is used for the sanitary facilities, and is pumped to the sanitary lagoon for treatment with final disposal in the adjacent waterway. The incinerator process water discharged into the canal near the plant was approximately the same quality as the well water, the original source of the process water. This is seen in comparing various quality measurements of the settling lagoon effluent and the well water: total solids--1,254 to 952 mg per liter; alkalinity--313 to 354 mg $CaCO_3$ per liter; chloride content--448 to 422 mg per liter; hardness--103 to 29 mg $CaCO_3$ per liter, phosphate--3.1 to 0.9 mg PO_4 per liter; and sulfate--68 to 20 mg SO_4 per liter.

TABLE XIV
WATER QUALITY RESULTS

Sample	Date	Temperature C		pH in field		pH in lab	Total solids mg/liter	Total solids volatile mg/liter	Total suspended solids mg/liter	Total suspended solids volatile mg/liter	Dissolved solids mg/liter
		Grab No. 1	Grab No. 2	Grab No. 1	Grab No. 2						
Spray water	Feb. 11	39	47	8.6	8.9	10.10	1,742	165	502	67	1,240
	Feb. 12	39	40	7.7	7.5	7.90	3,358	223	862	109	2,496
	Feb. 12	40	35	10.3	10.0	10.00	5,915	392	3,468	272	2,447
	Feb. 12	40	34	9.7	9.6	8.02	2,936	172	553	53	2,383
	Feb. 13	40	34	8.0	9.4	8.55	2,910	156	640	54	2,270
	Feb. 13	44	43	8.2	6.6	8.65	4,522	474	1,124	93	3,398
Spray, quench, fly ash sluicing, water mixture	Feb. 11	31	32	10.4	10.2	9.35	5,184	362	2,550	230	2,634
	Feb. 11	32	31	9.4	10.0	10.00	1,687	129	472	52	1,215
	Feb. 12	31	30	10.3	10.0	10.18	1,523	104	354	37	1,169
	Feb. 12	30	30	9.7	9.6	9.80	1,588	136	406	31	1,182
	Feb. 13	30	30	9.9	10.9	10.10	1,644	143	490	44	1,154
	Feb. 13	31	31	10.9	10.3	10.25	1,784	141	519	34	1,265
Fly ash sluicing water	Feb. 11	--	15	11.6	11.6	11.70	3,680	330	2,848	254	832
	Feb. 11	14	15	10.9	11.6	11.80	2,816	236	1,669	122	1,147
	Feb. 12	14	14	12.0	11.5	11.65	5,093	454	4,159	369	934
	Feb. 12	15	14	11.2	11.8	11.60	3,620	402	2,912	330	708
	Feb. 13	15	15	11.2	12.4	11.73	5,156	459	4,308	372	848
	Feb. 13	14	14	12.5	12.1	12.18	12,943	696	10,531	598	2,412

TABLE XIV (Continued)
WATER QUALITY RESULTS

Sample	Date	Temperature C		pH in field		pH in lab	Total solids mg/liter	Total solids volatile mg/liter	Total suspended solids mg/liter	Total suspended solids volatile mg/liter	Dissolved solids mg/liter
		Grab No. 1	Grab No. 2	Grab No. 1	Grab No. 2						
Lagoon effluent	Feb. 11	--	20	9.8	9.4	9.47	1,208	134	30	30	1,169
	Feb. 11	21	20	9.5	9.7	9.70	1,204	124	36	28	1,168
	Feb. 12	21	21	9.9	9.0	9.85	1,260	113	36	12	1,224
	Feb. 12	17	23	9.5	10.0	9.87	1,270	91	50	8	1,220
	Feb. 13	23	23	9.6	10.0	9.90	1,291	126	43	15	1,248
	Feb. 13	19	20	10.3	10.1	10.00	1,292	124	60	13	1,232
Well water	Feb. 11	24	--	7.0	--	8.45	964	83	0	0	964
	Feb. 12	25	--	8.1	--	8.45	947	72	0	0	947
	Feb. 13	24	--	8.4	--	8.29	945	60	0	0	945
Sanitary lagoon effluent	Feb. 13	--	--	--	--	7.35	1,648	487	371	314	1,277
Average spray water		40					3,564	264	1,192	108	2,372
Average spray, quench, fly ash sluicing water mixture		31					2,235	169	798	72	1,436
Average fly ash sluicing water		14					5,551	430	4,404	341	1,147
Average lagoon effluent		21					1,254	119	44	18	1,210
Average well water		24					952	72	0	0	952

TABLE XIV (Continued)
WATER QUALITY RESULTS

Sample	Date	Chloride mg/liter	Sulfate mg SO_4/liter	Phosphate mg PO_4/liter	Alkalinity mg $CaCO_3$/liter	Hardness mg $CaCO_3$/liter	Conductivities µmhos/cm
Spray water	Feb. 11	456	54.0	18.9	493	113	1,975
	Feb. 12	1,151	179.0	66.7	239	414	3,900
	Feb. 12	1,101	230.0	72.5	794	412	3,800
	Feb. 12	1,055	206.0	20.5	264	400	3,800
	Feb. 13	1,005	192.0	18.0	293	391	3,600
	Feb. 13	1,529	263.0	60.0	242	656	5,000
Spray, quench, fly ash sluicing, water mixture	Feb. 11	1,201	230.0	176.0	378	489	4,200
	Feb. 11	467	53.0	19.3	453	96	2,000
	Feb. 12	442	32.0	13.4	434	104	1,900
	Feb. 12	416	44.0	17.3	493	106	1,900
	Feb. 13	417	51.0	13.5	479	83	1,900
	Feb. 13	491	63.0	16.5	479	86	2,010
Fly ash sluicing water	Feb. 11	217	102.0	121.0	493	309	1,550
	Feb. 11	385	98.0	181.0	756	352	2,150
	Feb. 12	258	85.0	174.0	864	360	1,750
	Feb. 12	160	86.0	97.9	560	305	1,290
	Feb. 13	205	73.0	223.0	929	400	1,700
	Feb. 13	992	208.0	600.0	2,590	1,024	5,400

TABLE XIV (Continued)
WATER QUALITY RESULTS

Sample	Date	Chloride mg/liter	Sulfate mg SO_4/liter	Phosphate mg PO_4/liter	Alkalinity mg $CaCO_3$/liter	Hardness mg $CaCO_3$/liter	Conductivities µmhos/cm
Lagoon effluent	Feb. 11	433	68.0	4.4	308	107	1,900
	Feb. 11	439	73.0	1.8	309	105	1,950
	Feb. 12	452	67.0	3.7	314	107	1,950
	Feb. 12	452	68.0	2.4	314	106	2,000
	Feb. 13	455	67.0	3.2	316	104	2,000
	Feb. 13	455	65.0	3.1	318	89	1,980
Well water	Feb. 11	312	18.0	0.6	356	33	860
	Feb. 12	635	19.4	0.6	354	27	1,550
	Feb. 13	320	24.0	1.6	351	28	1,560
Sanitary lagoon effluent		481	63.0	3.4	342	352	1,550
Average spray water		1,050	187.3	42.8	388	398	3,680
Average spray, quench, fly ash sluicing water mixture		572	82.3	42.7	456	161	2,320
Average fly ash sluicing water		370	108.7	232.8	1,032	458	2,310
Average lagoon effluent		448	68.0	3.1	313	103	1,960
Average well water		442	20.5	0.9	354	29	1,550

Instrumentation

A record of all the readings taken during each stack test appears in Appendix III.

Industrial Hygiene

An industrial hygiene survey of the incinerator was made during the study period. The potential hazards investigated were: excessive dust, heat, and noise exposure, and inadequate lighting. The results of this survey are shown in Table XV. This survey found that during the study period the dust concentration and noise levels were below maximum permissible levels and presented no health hazard. The potential heat stress presented no health hazard at the time of the study period, but when the outdoor temperature does exceed 75 F, the heat stress may be excessive on the charging floor, the fan platform, and between the furnaces at the quench tank end. The illumination in the incinerator was adequate except for the areas between the furnaces and outside walls. The lights in these areas were inoperative during the study period due to faulty breaker switches and have subsequently been repaired.

Biological

A bacteriological study of the incinerator was made. Total microbial count, aerobic spores, anaerobic spores, and total and

TABLE XV

RESULTS OF INDUSTRIAL HYGIENE SURVEY

Location	Sound level			Heat stress			Dust	Light
	Network							
	A (db)	B (db)	C (db)	Dry (F)	Wet (F)	Globe Temperature (F)	(mg/m^3)	(fc)
Between hoppers on charging floor	89	91	93	75½	60	77	0.10	35
West end of charging floor (crane cab)	75	81	86				0.05	30
East end of charging floor	82	83	85					25
Fan platform (second floor) above control room*	92	94	96	85½	66	95½		50
Fan platform, back wall (west)	87	89	93					40
Fan platform, back wall (east)	85	88	91					45
Between furnace and west wall, first floor	88	91	94					< 5
Between furnace and west wall, first floor	85	88	92					< 5
At quench end of furnace	85	87	93					< 5
Between furnaces, at quench end	87	90	93	72	60	88		20
Between furnaces, just outside control room	87	90	93				0.05	60
Between furnace and east wall, quench end	85	88	91					< 5
Between furnace and east wall, feed end	87	89	92					< 5

*Only an occasional working area.
Outside temperature: 68 F, relative humidity, 60%
Standards: Sound--T.L.V. for db A: 90 for 8 hr/day, 92 for 6 hr/day (see reference 8)
Dust--T.L.V.: 15 mg/m^3 (see reference 9)
Light--Minimum: 5 ft candles--storage area, 10 fc--general area, and 20 fc--materials handling area (see reference 10)
Heat--(see reference 11)
T.L.V. = threshold limit value

fecal coliforms were quantitatively reported, while salmonellae was only reported qualitatively. The results of this study are shown in Table XVI. The study found that a comparison of the organisms in the solid waste and the residue showed a million fold reduction of total organisms per gram of material tested, while heat resistant aerobic and anaerobic spores showed a 1,000 to 100,000 fold reduction. Also, fecal coliform organisms were recovered from the solid waste and residue while salmonellae was recovered from one solid waste sample.

TABLE XVI

RESULTS OF BACTERIOLOGICAL STUDY

Source	Date	Total microbial count	Aerobic spore count	Anaerobic spore count	Coliform count		Salmonella
					Total	Fecal	
Solid waste	Feb. 10	4.0×10^8/gm	9.0×10^4/gm	7.5×10^3/gm	1.3×10^7/gm	2.9×10^6/gm	Salmonellae*
	Feb. 11	2.1×10^7/gm	3.5×10^4/gm	1.6×10^4/gm	4.2×10^6/gm	3.0×10^6/gm	N.I.
	Feb. 12	4.8×10^8/gm	3.4×10^5/gm	4.7×10^4/gm	--	3.2×10^8/gm	N.I.
Residue	Feb. 10	1.5×10^2/gm	3.0×10^1/gm	1.0×10^1/gm	N.D.	N.D.	N.I.
	Feb. 11	1.0×10^1/gm	1.0×10^1/gm	N.D.	N.D.	N.D.	N.I.
	Feb. 12	3.9×10^2/gm	1.0×10^1/gm	N.D.	N.D.	N.D.	N.I.
Quench water	Feb. 10	3.7×10^5/100 ml	1.3×10^4/100 ml	1.2×10^4/100 ml	4.6×10^4/100 ml	4.3×10^4/100 ml	N.I.
	Feb. 11	4.3×10^6/100 ml	3.5×10^3/100 ml	1.3×10^3/100 ml	1.7×10^4/100 ml	4.0×10^3/100 ml	N.I.
	Feb. 12	5.4×10^6/100 ml	1.5×10^4/100 ml	2.4×10^4/100 ml	2.3×10^4/100 ml	2.9×10^3/100 ml	N.I.
Stack	Feb. 10	N.D.	N.D.	N.D.	--	--	--
	Feb. 11	N.D.	N.D.	N.D.	--	--	--
	Feb. 12	--	--	--	--	--	--
Fly ash	Feb. 12	N.D.	N.D.	N.D.	--	--	--
Well water	Feb. 11	8.0×10^2/100 ml	11.0×10^2/100 ml	N.D.	N.D.	N.D.	--
	Feb. 12	1.3×10^5/100 ml	1.0×10^2/100 ml	N.D.	N.D.	N.D.	--

N.D. - No counts detected in testing sample (see reference 6)
N.I. - Not isolated
*Salmonella give and Salmonella st. paul

COST ANALYSIS

The following cost analysis is based upon information provided by the officials of the City of New Orleans. The data are for the calendar year 1968, and the overall costs are shown in Table XVII.

One assumption was made and several different features were involved in developing this information. The assumption was the use of the facility life of 25 years which was estimated by officials of the City of New Orleans. The first feature was the cost of residue disposal; this cost was determined from the costs incurred by the municipally owned and operated landfill. The second was the interest cost of the bonds; this interest may not be representative of other community rates or repayment schedules. A simple interest calculation was used. The last was the lack of repair costs; this lack was due to the manufacturer's warranty which was still in effect at the time of the study.

Based upon the information provided and the assumption and features detailed above, the operating and ownership cost of the facility for the calendar year 1968 was $442,156. The facility processed 47,250 tons of solid waste for a unit cost of $9.63 per ton. It is important to note that the tonnage received in calendar year 1968 averaged only 160 tons per day during the first year of operation. The incinerator is designed for 400 tons per day, and it was running at this rate in the beginning of the calendar year 1969. Table XVIII gives a cost comparison of the incinerator at the actual 1968 operating level versus

the operation at design capacity. In this comparison, the repair costs were assumed to increase linearly with the increase in capacity.

In a further effort to define expenditures involved in incinerator operation, an analysis has been made on the allocation of cost by cost centers and a breakdown of repairs and maintenance by cost centers, as shown in Table XIX.

TABLE XVII

NEW ORLEANS EAST INCINERATOR
1968 ANNUAL COST BREAKDOWN

	$	$/ton	%
Direct labor (includes 12.5% fringes)	$160,949	$3.40	37
Utilities (electric and gas)	31,952	.68	7
Parts and supplies	2,700	.06	1
Vehicle operating expenses	13,968	.30	3
External repair charges	808	.02	0
Allocated disposal charges	27,720	.38	6
Overhead	21,331	.45	5
Total annual operating cost	$259,428	5.49	59
Plant depreciation (Cost $2,530,855; life 25 years)	101,234	2.14	23
Interest at 3.219%	61,494	1.73	18
Total annual financing and ownership costs	182,728	3.87	41
Total annual cost	$442,156	$9.36	100

TABLE XVIII

COST PROJECTIONS FOR FULL CAPACITY

	Actual results (160 tons/day)		Projections (400 tons/day)	
	$	$/ton	$	$/ton
Direct labor	160,949	3.40	160,949	1.37
Utilities	31,952	.68	79,880	.68
Parts and supplies	2,700	.06	6,750	.06
Vehicle operating expense	13,968	.30	34,920	.30
External repair charges	808	.02	2,020	.02
Disposal charges	27,720	.58	69,300	.58
Overhead	21,331	.45	21,331	.17
Total operating costs	259,428	5.49	375,150	3.18
Depreciation	101,234	2.14	101,234	.86
Interest	81,494	1.73	81,494	.69
Total ownership	182,728	3.87	182,728	1.55
Total	$442,156	$9.36	$557,878	$4.73

TABLE XIX

OPERATING COST BREAKDOWN
BY COST CENTERS

Repairs and Maintenance

Labor	$44,003	Receiving	$18,642
Parts	2,700	Volume reduction	17,834
External charges	808	Effluent treatment	17,834
Overhead	6,799		
Total	$54,310	Total	$54,310

Receiving	$	%
Direct labor	$ 73,360	
Utilities	18,720	
Repairs and maintenance	18,642	
Overhead	9,081	
Total	119,803	46
Volume reduction		
Direct labor	14,260	
Utilities	6,193	
Repairs and maintenance	17,834	
Overhead	1,819	
Total	40,106	16
Effluent handling and treatment		
Direct labor	29,326	
Utilities	7,039	
Vehicle operating expense	13,968	
Disposal charges	27,720	
Repairs and maintenance	17,834	
Overhead	3,632	
Total	99,519	38
Total	$259,428	100

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APPENDIX I

HEAT CONTENT: EXAMPLE CALCULATIONS

Using the data from the laboratory analyses of solid waste sample No. 1 (Chart 1), this example calculation shows the method used to calculate the moisture content, ash and volatile content, and heat content of the total sample. The laboratory determined that the combustible portion of the sample contained 33.2 percent moisture, 86.2 percent volatiles and 13.8 percent ash on a dry basis, and a heat content of 8,395 Btu per lb on a dry basis. The field separation determined a combustible content of 77.2 percent on a wet basis. The assumption was made that the noncombustibles had no moisture content, no heat content, and were treated as "ash."

Chart 1

RESULTS OF PROXIMATE ANALYSIS OF COMBUSTIBLE PORTION OF INCOMING SOLID WASTE SAMPLES

Sample	Wet basis	Dry basis			
	Combustible content %	H_2O %	Volatiles %	Ash %	Heat content Btu/lb
1	77.2	33.2	86.2	13.8	8,395
3	73.1	39.5	87.0	13.0	8,190
5	80.0	35.6	90.8	9.2	8,200
8	71.9	41.3	85.5	14.5	7,845

Since the moisture in the total sample is in the combustible portion, the percent moisture in the total sample is calculated by the following method:

$$\text{Percent moisture in total sample} = \left(\frac{\text{lb combustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb combustibles}}\right) 100$$

$$\text{Percent moisture in total sample} = \left(\frac{0.772 \text{ lb combustibles}}{\text{lb waste}}\right)\left(\frac{0.332 \text{ lb moisture}}{\text{lb combustibles}}\right) 100.0 = 25.6$$

The volatiles are calculated on a dry basis. The percent combustibles must be converted to a dry basis by the following method:

$$\text{Percent combustibles in total sample} = 100 - \text{percent moisture} - \text{percent noncombustibles}$$

$$\text{Percent combustibles in total sample} = 100.0-25.6 - 22.8 = 51.6$$

$$\text{Percent dry combustibles} = \frac{\text{percent combustibles}}{\text{1- moisture content}}$$

$$\text{Percent dry combustibles} = \frac{51.6}{1-0.256} = 69.4$$

The percent volatiles and ash are calculated by the following methods:

$$\text{Percent volatiles in total dry sample} = \left(\frac{\text{lb volatiles}}{\text{lb dry combustibles}}\right)\left(\frac{\text{lb dry combustibles}}{\text{lb waste}}\right) 100$$

$$\text{Percent volatiles in total dry sample} = \left(\frac{0.862 \text{ lb dry volatiles}}{\text{lb dry combustibles}}\right)\left(\frac{0.694 \text{ lb dry combustibles}}{\text{lb waste}}\right) 100.0$$

$$= 59.8$$

$$\text{Percent ash in total dry sample} = 100 - \text{percent volatiles}$$

$$\text{Percent ash in total dry sample} = 100.0 - 59.8 = 40.2$$

$$\text{Percent volatiles in total "as received" sample} = \left(\text{percent volatiles in total dry sample}\right)\left(\frac{100 - \text{percent moisture}}{100}\right)$$

$$= (59.8)\ (0.744) = 44.5$$

$$\text{Percent ash in total "as received" sample} = \left(\text{percent ash in total dry sample}\right)\left(\frac{100 - \text{percent moisture}}{100}\right)$$

$$= (40.2)\ (0.744) = 29.9$$

Since the laboratory reports the heat content on a dry basis for the combustibles only, the moisture content and the noncombustibles in the total sample must be accounted for when calculating the heat content of the total sample.

$$\text{Btu per lb "as received"} = \left(\text{Btu/dry lb}\right)\left(\frac{100 - (\text{percent moisture} + \text{percent noncombustibles})}{100}\right)$$

$$\text{Btu per lb "as received"} = \left(8{,}395 \text{ Btu/dry lb}\right)\left(\frac{100.0 \text{ percent} - (25.6 \text{ percent} + 22.8 \text{ percent})}{100.0 \text{ percent}}\right)$$

$$\text{Btu per lb "as received"} = 4{,}332$$

Using the data from the laboratory analysis of residue sample No. 1 (Chart No. 2), this example calculation shows the methods used to calculate the moisture content, ash and volatile content, and heat content of the total sample.

The amount of fines and unburned combustibles found during the field separation of residue sample No. 1 was 57.3 and 0.6 percent respectively on a wet basis. The assumption was made that the glass and rocks and metals contained no moisture, no heat, and were treated as "ash."

Since the moisture in the total sample is in the fines and unburned combustibles, the percent moisture in the total sample is calculated by the following method:

$$\text{Percent moisture in total sample} = \left[\left(\frac{\text{lb fines}}{\text{lb residue}}\right)\left(\frac{\text{lb water}}{\text{lb fines}}\right) + \left(\frac{\text{lb unburned combustibles}}{\text{lb residue}}\right)\left(\frac{\text{lb water}}{\text{lb unburned combustibles}}\right)\right] \times 100$$

$$\text{Percent moisture in total sample} = \left[\left(\frac{0.573 \text{ lb fines}}{\text{lb residue}}\right)\left(\frac{0.209 \text{ lb water}}{\text{lb fines}}\right) + \left(\frac{0.006 \text{ lb unburned combustibles}}{\text{lb residue}}\right)\left(\frac{0.443 \text{ lb water}}{\text{lb unburned combustibles}}\right)\right] \times 100 = 12.2\%$$

Because the remaining calculations are on a dry basis, the separation data must be converted to a dry basis.

$$\text{Percent dry component} = \left[\frac{(\text{lb wet component}) - (\text{lb water in wet component})}{\text{total sample weight, dry}}\right] 100.0$$

These calculations are summarized in the following chart:

Component	Weight lb	Moisture %	Water lb	Dry weight lb	Percent (dry)
Fines	26.00	20.9	5.43	20.57	51.67
Unburned combustibles	0.25	44.3	0.11	.14	0.36
Glass and rocks	9.50	0.0		9.50	23.86
Metal	9.60	0.0		9.60	24.11
Total	45.35			39.81	100.00

The percent volatiles and ash are calculated for the total sample by the following method:

$$\text{Percent volatiles} = \left[\left(\frac{\text{lb volatiles}}{\text{lb fines}}\right)\left(\frac{\text{lb fines}}{\text{lb residue}}\right) + \left(\frac{\text{lb volatiles}}{\text{lb unburned combustibles}}\right)\left(\frac{\text{lb unburned combustibles}}{\text{lb residue}}\right)\right] 100$$

$$\text{Percent volatiles} = \left[\left(\frac{0.016 \text{ lb volatiles}}{\text{lb fines}}\right)\left(\frac{0.5167 \text{ lb fines}}{\text{lb residue}}\right) + \left(\frac{0.291 \text{ lb volatiles}}{\text{lb unburned combustibles}}\right)\left(\frac{0.0036 \text{ lb unburned combustibles}}{\text{lb residue}}\right)\right] 100.0$$

Percent volatiles = 0.91

Percent ash = 100 - percent volatiles

Percent ash = 100.0 - 0.91 = 99.09

The heat content is calculated on a dry basis by the following method:

$$\text{Btu per lb} = \left(\frac{\text{Btu}}{\text{lb fines}}\right)\left(\frac{\text{lb fines}}{\text{lb residue}}\right) + \left(\frac{\text{Btu}}{\text{lb unburned combustibles}}\right)\left(\frac{\text{lb unburned combustibles}}{\text{lb residue}}\right)$$

$$\text{Btu per lb} = \left(\frac{175 \text{ Btu}}{\text{lb fines}}\right)\left(\frac{0.5167 \text{ lb fines}}{\text{lb residue}}\right) + \left(\frac{3{,}290 \text{ Btu}}{\text{lb unburned combustibles}}\right)\left(\frac{0.0036 \text{ lb unburned combustibles}}{\text{lb residue}}\right) = 103$$

Chart 2 gives the laboratory analysis results necessary for the above calculations.

Chart 2

RESULTS OF PROXIMATE ANALYSIS OF FINES AND UNBURNED COMBUSTIBLES PORTIONS OF RESIDUE SAMPLES

Sample	Fines				Unburned combustibles			
	% H_2O	% Volatiles	% Ash	Heat content (dry) Btu/lb	% H_2O	% Volatiles	% Ash	Heat content (dry) Btu/lb
1	20.9	1.6	98.4	175	44.3	29.1	70.9	3,290
2	15.2	0.5	99.5	120	14.0	2.1	97.9	100
3	12.5	0.6	99.4	130	52.1	18.1	81.9	1,730
4	15.5	0.8	99.2	85	59.4	21.3	78.7	2,060

Since the complete fly ash sample is returned to the laboratory for analysis, the heat content and ash and volatile content values reported by the laboratory (on a dry basis) are values for the total sample and no further calculation is required.

APPENDIX II

COMBUSTION EFFICIENCIES: EXAMPLE CALCULATIONS

Total Weight Reduction

The total weight reduction of the plant on a dry basis can be calculated by dividing the total tons of dry effluents by the total tons of dry influents and subtracting this value from one. The effluents include the residue, the fly ash going out the stack and the solids in the wastewater. The influent is the total tonnage of dry solid waste. The following formula is used:

$$\text{Percent weight reduction (dry basis)} = \left[1 - \left(\frac{\text{total tons dry residue + total tons dry fly ash}}{\text{total tons dry solid waste}} + \frac{\text{total tons dry solids in wastewater}^{*}}{\text{total tons dry solid waste}}\right)\right] \times 100$$

For the week of the study, the following weight reduction was found:

$$\text{Percent weight reduction} = \left[1 - \left(\frac{390 + 11}{851}\right)\right] \times 100 = 52.9$$

It should be noted that the weight of dry fly ash emitted was determined from stack emission tests as follows:

$$\text{Weight of dry fly ash} = (\text{weight of fly ash emitted per hr})(\text{hr of operation})$$

$$\text{Weight of dry fly ash} = \left(\frac{193 \text{ lb fly ash}}{\text{hr}}\right)\left(118 \text{ hr}\right)\left(\frac{1 \text{ ton}}{2{,}000 \text{ lb}}\right) = 11 \text{ tons}$$

*not measured

Total Volume Reduction

The total volume reduction of the plant is calculated on an "as received" basis because the density determination was made on the "as received" material. The following formula is used:

$$\text{Percent volume reduction ("as received" basis)} =$$

$$\left[1 - \frac{\left(\frac{\text{total lb "as sampled" residue}}{\text{density of "as sampled" residue}}\right) + \left(\frac{\text{total lb "as sampled" fly ash}}{\text{density of "as sampled" fly ash}}\right)}{\frac{\text{total lb of "as received" solid waste}}{\text{density of "as received" solid waste}}} + \frac{\left(\frac{\text{total lb "as sampled" wastewater solids}}{\text{density of "as sampled" wastewater solids}}\right)^{*}}{\frac{\text{total lb of "as received" solid waste}}{\text{density of "as received" solid waste}}} \right] \times 100$$

For the week of the study, the following volume reduction was found:

$$\text{Percent volume reduction} = \left[1 - \left(\frac{872{,}000/1{,}600 + 22{,}000/1{,}140}{2{,}370{,}000/230}\right) \right] \times 100 = 94.5\%$$

Volatile Weight Reduction

The volatile weight reduction of the plant can be calculated by dividing the volatile fraction of the total solid effluents by the volatile fraction of the total solid influent and subtracting this value from one. The following formula is used:

*not measured

Percent volatile reduction =

$$\left[1 - \left(\frac{\text{total tons residue x percent volatile + total tons fly ash x percent volatiles}}{\text{total tons solid waste x percent volatiles}} + \frac{\text{total tons solids in wastewater}^{*} \text{ x percent volatiles}}{\text{total tons solid waste x percent volatiles}}\right)\right] \times 100$$

For the study, the following volatile weight reduction was found:

$$\text{Volatile weight reduction} = \left[1 - \left(\frac{390 \times 0.0056 + 11 \times 0.042}{1{,}185 \times 0.414}\right)\right] \times 100 = 99.6\%$$

Percent of Available Heat Released

To obtain the percent of available heat released, the heat in the incoming solid waste, residue and fly ash for the week must be calculated by multiplying the total weights by the average Btu content.

The percent of available heat released is calculated by:

$$\text{Percent of available heat released} = \left[1 - \left(\frac{\text{Btu/lb residue x lb residue}}{\text{Btu/lb solid waste x lb solid waste}} + \frac{\text{Btu/lb fly ash x lb fly ash}}{\text{Btu/lb solid waste x lb solid waste}} + \frac{\text{Btu/lb wastewater solids}^{*} \text{ x lb wastewater solids}^{*}}{\text{Btu/lb solid waste x lb solid waste}}\right)\right] \times 100$$

$$= \left[1 - \left(\frac{71 \times 390 \times 2{,}000 + 442 \times 193 \times 118}{3{,}872 \times 1{,}185 \times 2{,}000}\right)\right] \times 100 = 99.3\%$$

*not measured

APPENDIX III

INSTRUMENTATION AND VISIBLE EMISSIONS DURING STACK TESTS

FOR FURNACE NO. 2

INSTRUMENTATION READINGS DURING STACK TESTS

Date 2-11-69	Temperature (F)			Draft (in. H_2O)			Control settings			Grate control setting (strokes per min)					
										Front to back of furnace					
Time	Primary chamber	Collector inlet	Flame	Under-fire air	Over-fire air	Furnace	Under-fire air damper	Automatic overfire air	Spray H_2O	1	2	3	4	5	Stack test no.
10:55	1950	550	2550	1.4	11.5	0.24	off	off	11.0	0.5	0.5	12.0	2.3	10.0	1
11:05	1980	550	2450	0.8	11.5	0.22	off	off	6.5	0.5	0.5	3.0	2.3	10.0	1
11:15	1920	550	2400	0.8	11.5	0.24	off	off	7.0	0.5	0.5	3.0	2.3	10.0	1
11:25	2000	550	2450	0.8	11.5	0.22	off	off	7.5	0.5	0.5	3.0	2.3	10.0	1
11:35	2080	550	2500	1.2	11.5	0.23	off	off	12.0	0.5	0.5	3.0	2.3	10.0	1
11:45	2060	550	2550	0.9	11.5	0.22	7.0	off	8.5	0.5	0.5	3.0	2.3	10.0	1
11:55	2000	550	2450	0.9	11.5	0.22	7.0	off	7.5	0.5	0.5	3.0	2.3	10.0	1
12:05	2080	540	2550	1.0	11.5	0.23	3.1	off	10.0	0.5	0.5	3.0	2.3	10.0	1
12:15	2000	550	2550	1.1	11.5	0.22	3.1	off	8.5	0.5	0.5	3.0	2.3	10.8	1
12:25	2120	540	2400	0.8	11.5	0.22	7.0	off	8.5	0.5	0.5	3.0	2.3	10.8	1
12:35	2000	550	2350	0.7	11.5	0.24	7.0	off	7.5	0.5	0.5	3.0	2.3	10.8	1
12:45	1900	550	2250	0.7	11.5	0.24	7.0	off	5.5	0.5	0.5	3.0	2.3	10.8	1

INSTRUMENTATION READINGS DURING STACK TESTS (continued)

Date 2-11-69	Temperature (F)			Draft (in. H_2O)			Control settings			Grate control setting (strokes per min)					Stack test no.
										Front to back of furnace					
Time	Primary chamber	Collector inlet	Flame	Under-fire air	Over-fire air	Furnace	Under-fire air damper	Automatic overfire air	Spray H_2O	1	2	3	4	5	
2:15	2140	560	2500	1.1	11.5	0.22	4.8	off	12.0	0.75	0.75	3.0	2.3	12.0	2
2:25	2160	540	2550	0.8	11.5	0.22	6.0	off	9.0	0.75	0.75	3.0	2.3	12.0	2
2:35	2050	550	2550	0.8	11.5	0.22	8.1	off	8.5	0.75	0.75	3.0	2.3	12.0	2
2:45	1950	550	2650	0.9	11.5	0.24	8.1	off	8.0	0.75	0.75	2.3	2.3	12.0	2
2:55	2100	550	2650	1.1	11.5	0.22	5.1	off	11.0	0.75	0.75	2.3	2.3	12.0	2
3:05	2050	550	2500	1.2	11.5	0.24	5.1	off	11.0	0.75	0.75	2.3	2.3	12.0	2
3:15	1950	540	2400	1.1	11.5	0.24	5.1	off	8.5	0.75	0.75	2.3	2.3	12.0	2
4:05	2050	550	2450	1.1	11.5	0.24	5.1	off	11.0	0.75	0.75	2.8	2.3	12.0	3
4:15	2080	550	2550	1.0	11.5	0.24	5.1	off	12.0	0.75	0.75	2.8	2.2	12.0	3
4:25	2100	550	2550	1.0	11.5	0.20	6.1	off	10.5	0.75	0.75	2.8	2.2	12.0	3
4:35	2100	550	2500	0.9	11.5	0.24	7.0	off	9.0	0.75	0.75	2.8	2.2	12.0	3
4:45	2060	550	2600	0.4	11.5	0.24	10.2	off	6.5	0.75	0.75	2.8	2.2	12.0	3

INSTRUMENTATION READINGS DURING STACK TESTS (continued)

Date 2-12-69	Temperature (F)			Draft (in. H_2O)			Control settings			Grate control setting (strokes per min)					
										Front to back of furnace					
Time	Primary chamber	Collector inlet	Flame	Under-fire air	Over-fire air	Furnace	Under-fire air damper	Automatic overfire air	Spray H_2O	1	2	3	4	5	Stack test no.
9:10	1700	500	2400	0.6	1.5	0.40	off	14.0	7.0	0.2	0.4	2.0	2.4	12.0	4
9:20	1750	540	2250	0.6	1.5	0.40	off	14.0	7.0	0.2	0.4	2.0	2.4	12.0	4
9:30	2050	550	2350	1.0	11.5	0.40	6.0	off	10.0	0.1	0.2	2.0	2.4	12.0	4
9:40	1850	550	2100	1.2	11.5	0.40	6.0	5.0	9.0	0.1	0.2	1.8	3.0	12.0	4
9:50	1800	530	2100	0.8	1.5	0.40	5.0	14.0	7.0	0.1	0.2	1.8	3.0	12.0	4
10:40	1800	550	2100	0.6	1.5	0.40	6.0	14.0	7.0	0.2	0.2	2.0	3.0	12.0	5
10:50	1850	530	2050	0.6	1.5	0.40	6.0	14.0	7.0	0.2	0.2	2.0	3.0	12.0	5
11:00	1800	550	2150	0.6	1.5	0.40	6.0	14.0	6.5	0.2	0.2	2.0	3.0	12.0	5
11:10	2000	550	2150	0.8	11.5	0.40	6.0	off	8.0	0.2	0.2	1.8	3.0	12.0	5
11:20	2000	550	2300	0.8	11.5	0.40	6.0	off	9.0	0.2	0.2	1.8	3.0	12.0	5
11:30	2100	550	2400	0.8	11.5	0.40	6.4	off	9.0	0.2	0.2	1.8	3.0	12.0	5

INSTRUMENTATION READINGS DURING STACK TESTS (continued)

Date 2-12-69	Temperature (F)			Draft (in. H_2O)			Control settings			Grate control setting (strokes per min)					
										Front to back of furnace					
Time	Primary chamber	Collector inlet	Flame	Under-fire air	Over-fire air	Furnace	Under-fire air damper	Automatic overfire air	Spray H_2O	1	2	3	4	5	Stack test no.
1:10	1900	550	2300	0.9	11.5	0.40	6.5	off	8.0	0.2	0.2	1.8	3.0	12.0	6
1:20	2100	550	2300	0.8	11.5	0.40	6.5	off	8.0	0.2	0.2	1.8	3.0	12.0	6
1:30	2200	550	2400	0.6	11.5	0.40	7.3	off	8.0	0.2	0.2	1.8	2.8	12.0	6
1:40	2000	550	2450	0.6	11.5	0.40	7.3	off	6.0	0.2	0.2	1.8	2.8	12.0	6
1:50	2050	550	2250	0.6	11.5	0.40	7.6	off	6.0	0.2	0.2	1.8	2.8	12.0	6
2:40	2050	550	2400	0.8	11.5	0.40	6.9	off	8.0	0.2	0.2	2.4	3.2	12.0	7
2:50	1950	550	2400	1.0	11.5	0.40	6.9	off	8.0	0.2	0.4	2.2	3.2	12.0	7
3:00	1900	550	2450	0.8	11.5	0.40	6.9	off	7.8	0.2	0.4	2.2	3.2	12.0	7
3:10	1950	550	2400	0.8	11.5	0.40	6.9	off	8.0	0.6	0.6	2.2	3.2	12.0	7
3:20	1850	550	2450	0.9	9.0	0.40	7.1	11.0	6.2	0.6	0.6	2.2	3.2	12.0	7
3:30	1950	550	2300	0.8	11.5	0.40	7.1	off	8.0	0.6	0.6	2.2	3.2	12.0	7

INSTRUMENTATION READINGS DURING STACK TESTS (continued)

Date 2-13-69	Temperature (F)			Draft (in. H_2O)			Control settings			Grate control setting (strokes per min)					
										Front to back of furnace					
Time	Primary chamber	Collector inlet	Flame	Under-fire air	Over-fire air	Furnace	Under-fire air damper	Automatic overfire air	Spray H_2O	1	2	3	4	5	Stack test no.
9:20	1850	530	2150	0.6	4.8	0.44	8.9	12.1	7.8	0.6	0.6	2.4	3.2	11.8	8
9:30	1850	540	2100	0.6	3.2	0.46	9.0	11.5	5.1	0.6	0.6	2.4	3.2	11.8	8
9:40	1950	550	2300	0.7	12.0	0.44	8.9	off	8.8	0.6	0.6	2.4	3.2	11.8	8
9:50	2000	560	2250	0.6	12.0	0.45	8.9	off	6.6	0.6	0.6	2.4	3.2	11.8	8
10:00	1950	550	2150	0.6	11.8	0.46	8.9	off	8.5	0.6	0.6	2.4	3.2	11.8	8
10:10	1950	550	2150	0.6	12.0	0.44	8.9	off	11.0	0.6	0.6	2.4	3.2	11.8	8
10:20	1875	550	2100	0.6	11.8	0.45	8.9	5.8	7.8	0.6	0.6	2.4	3.2	11.8	8
11:10	2000	550	2225	0.6	12.0	0.46	8.9	off	8.5	0.6	0.6	2.4	3.2	11.8	9
11:20	2000	550	2175	0.6	11.9	0.45	8.9	off	8.2	0.6	0.6	2.4	3.2	11.8	9
11:30	1975	550	2125	0.7	12.0	0.45	8.9	off	7.8	0.6	0.6	2.4	3.2	11.8	9
11:40	1950	550	2050	0.7	12.0	0.45	8.9	off	8.4	0.6	0.6	2.4	3.2	11.8	9
11:50	1900	545	2100	0.7	11.9	0.46	8.9	off	7.5	0.6	0.6	2.4	3.2	11.8	9
12:00	2050	540	2200	0.6	11.9	0.46	8.9	off	8.2	0.6	0.6	2.4	3.2	11.8	9

VISIBLE EMISSIONS DURING STACK TESTS

Date	Time	Ringlemann	Opacity (%)	Stack test number
2-11-69	11:00	-	60	1
2-11-69	11:05	-	50	1
2-11-69	11:10	1.75	-	1
2-11-69	11:15	2.00	-	1
2-11-69	11:20	-	60	1
2-11-69	11:25	2.00	-	1
2-11-69	11:30	1.75	-	1
2-11-69	11:35	2.25	-	1
2-11-69	11:40	2.00	-	1
2-11-69	11:45	1.50	-	1
2-11-69	11:50	2.00	-	1
2-11-69	2:30	1.25	-	2
2-11-69	2:35	1.00	-	2
2-11-69	2:40	0.75	-	2
2-11-69	2:45	1.00	-	2
2-11-69	2:50	1.50	-	2
2-11-69	2:55	2.00	-	2
2-11-69	3:00	1.50	-	2
2-11-69	3:05	1.00	-	2

VISIBLE EMISSIONS DURING STACK TESTS (continued)

Date	Time	Ringlemann	Opacity (%)	Stack test number
2-11-69	4:15	2.00	-	3
2-11-69	4:20	1.75	-	3
2-11-69	4:25	1.75	-	3
2-11-69	4:30	2.00	-	3
2-11-69	4:35	2.00	-	3
2-11-69	4:40	1.75	-	3
2-11-69	4:45	1.75	-	3
2-11-69	4:50	1.50	-	3
2-11-69	4:55	1.50	-	3
2-11-69	5:00	1.75	-	3
2-12-69	9:10	-	25	4
2-12-69	9:15	-	15	4
2-12-69	9:20	-	10	4
2-12-69	9:25	1.00	-	4
2-12-69	9:30	1.50	-	4
2-12-69	9:35	-	50	4
2-12-69	9:40	-	50	4
2-12-69	9:45	-	30	4
2-12-69	9:50	-	30	4
2-12-69	9:55	-	15	4

VISIBLE EMISSIONS DURING STACK TESTS (continued)

Date	Time	Ringlemann	Opacity (%)	Stack test number
2-12-69	10:45	-	30	5
2-12-69	10:50	-	10	5
2-12-69	10:55	-	15	5
2-12-69	11:00	-	15	5
2-12-69	11:05	-	10	5
2-12-69	11:10	1.00	-	5
2-12-69	11:15	1.50	-	5
2-12-69	11:20	-	40	5
2-12-69	11:25	-	20	5
2-12-69	1:15	1.00	-	6
2-12-69	1:20	0.75	-	6
2-12-69	1:25	1.00	-	6
2-12-69	1:30	0.75	-	6
2-12-69	1:35	0.75	-	6
2-12-69	1:40	1.00	-	6
2-12-69	1:45	0.75	-	6
2-12-69	1:50	1.25	-	6
2-12-69	1:55	1.00	-	6

VISIBLE EMISSIONS DURING STACK TESTS (continued)

Date	Time	Ringlemann	Opacity (%)	Stack test number
2-12-69	2:40	1.25	-	7
2-12-69	2:45	1.25	-	7
2-12-69	2:50	0.75	-	7
2-12-69	2:55	1.75	-	7
2-12-69	3:00	1.75	-	7
2-12-69	3:05	1.50	-	7
2-12-69	3:10	1.25	-	7
2-12-69	3:15	1.00	-	7
2-12-69	3:20	0.75	-	7
2-13-69	9:15	-	40	8
2-13-69	9:20	-	60	8
2-13-69	9:25	-	40	8
2-13-69	9:30	-	40	8
2-13-69	9:35	-	50	8
2-13-69	9:40	-	55	8
2-13-69	9:45	-	40	8
2-13-69	9:50	-	60	8
2-13-69	9:55	-	60	8
2-13-69	10:00	-	40	8

VISIBLE EMISSIONS DURING STACK TESTS (continued)

Date	Time	Ringlemann	Opacity (%)	Stack test number
2-13-69	11:20	-	60	9
2-13-69	11:25	-	45	9
2-13-69	11:30	-	40	9
2-13-69	11:35	-	30	9
2-13-69	11:40	-	35	9
2-13-69	11:45	-	25	9
2-13-69	11:50	-	15	9
2-13-69	11:55	-	40	9
2-13-69	12:00	-	30	9